# Cumulative Effects of a Severe Windstorm and Subsequent Silvicultural Treatments on Plant and Arthropod Diversity in The Gunflint Corridor of the Superior National Forest in Northern Minnesota: Project Design

DW Gilmore, SJ Seybold, JC Zasada,
PJ Anderson, DN Kastendick, KJK Gandhi and HP Johnson

ABSTRACT. On July 4th 1999, unprecedented derechos, also known as thunderstorm downbursts (wind speeds of 75 to 110 mph), caused damage to approximately 477,000 acres of sub-boreal forest in the Superior National Forest, including the Boundary Waters Canoe Area Wilderness (BWCAW). No harvesting or salvage activity is permitted in the BWCAW although prescribed burns to reduce fuel loadings have and will be conducted. Alternative fuel reduction treatments intended to reduce the risk of fire and insect and disease outbreaks are in progress in the Gunflint Corridor that is surrounded by the BWCAW. These treatments include: (a) prescribed burning; (b) salvage-harvesting; and (c) piling and burning of wind thrown trees. During the fall of 1999 and summers of 2000 & 2001, we collected pre- and post-treatment data on plots established to monitor plant succession and arthropod diversity within each of two forest cover types (jack pine and aspen/birch), on 1) undisturbed sites; 2) severely wind-disturbed sites (67-100% tree mortality) that were not treated; 3) severely wind-disturbed sites that were salvaged logged; 4) on sites treated with prescribed burns; and 5) machine-piled sites with and without burning piles.

KEY WORDS. arthropods, bark beetles, derecho, entomology, forest productivity, fuel reduction, regeneration, salvage logging, silviculture, wildfire

## INTRODUCTION

The natural disturbance paradigm is based on the premise that forests can be manipulated through harvesting, site preparation treatments, and tree planting to approximate conditions that would occur following a natural disturbance (Seymour and Hunter 1992). Multiple disturbances, however, can have an additive effect on forest species composition and community ecology. For example, if two crown fires occur 50 years apart in a jack pine forest, following the second fire there would be adequate seed storage in the serontinous cones to regenerate a jack pine forest. If the two fires were only 10 years apart, however, the second fire could leave the forest with little or no jack pine seed source thereby creating an opportunity for another species to dominate the site. Consecutive natural and human caused disturbances, such as severe winds followed by salvage logging, have been shown to affect tree species composition, soil stability, nutrient availability, and stream hydrology (Foster et al. 1997, Frelich and Reich 1998). Forest resource managers are constantly striving to improve silvicultural practices to maintain ecosystem stability, productivity and diversity (Attiwill 1994, Lieffers et al. 1996). Wildfires have historically determined tree composition and stand age structure in the mesic forests of northern Minnesota (Heinselman 1973, Ohmann and Grigal 1979). Several workers have hypothesized that fire suppression during the last century in the BWCAW is responsible for altered forest processes such as insufficient regeneration of pines and a dominance of older forest stands that may result in increased insect and disease outbreaks (Heinselman 1973, Frelich and Reich 1995, Minnesota Forest Resources Council 1999). Managers of publicly owned lands in northern Minnesota should consider developing silvicultural practices that emulate wildfire, wind disturbance, and other natural disturbances (Frelich and Reich 1998, Palik and Robl 1999).

On July 4th 1999, unprecedented derechos, also know as thunderstorm downbursts (wind speeds of 75 to 110 mph), caused damage to approximately 477,000 acres of sub-boreal forest in the Superior National Forest, including the Boundary Waters Canoe Area Wilderness (BWCAW) (Figure 1). The BWCAW contains the majority of the area affected by the blow down (Table 1) and because it is an official wilderness area the only plans to reduce fuels and risk of wildfire are through prescribed burns (USDA Forest Service 2001). The USDA Forest Service is currently implementing three fuel reduction treatments on 4,714 acres in the Gunflint Corridor: (a) prescribed burning (2,118 acres); (b) salvage-harvesting (2,387 acres); and (c) piling of down trees with and without burning (140 acres) (USDA Forest Service 2000). This windstorm, coupled with fuel reduction treatments provides an opportunity for detailed examination of plant and animal community development following disturbances of both natural and natural plus anthropogenic origin. The objective of this study is to obtain post-blow down baseline data prior to fuel reduction treatments and monitor the effects of alternative fuel reduction treatments (primarily salvage harvesting and prescribed burning) on forest community development. More specifically, we have developed an umbrella experimental design to focus on hypotheses of forest productivity that includes nested studies focusing on tree regeneration, arthropod diversity, and soil nutrient dynamics.

## METHODS & MATERIALS

### Study Area

The Gunflint Corridor of the Superior National Forest is surrounded by the Boundary Waters Canoe Area Wilderness in northeastern Minnesota (Figure 1) with the majority of the land in federal ownership (Table 1). Climate is mid-continental with long, cold winters and warm summers. Mean annual precipitation is around 28 inches with temperature ranges between -46$^{\circ}$ F and 100$^{\circ}$ F (Alghren 1969). The mean annual temperature is 36$^{\circ}$ F with mean July and January temperatures of 62$^{\circ}$ F and -5$^{\circ}$ F, respectively (Baker and Strub 1965). The soils of the area are characterized by grayish brown tills, outwash, and lacustrine deposits from the Rainy glacial lobe of the Laurentide Ice Sheet. Depth to bedrock is an import factor in determining species composition and productivity and varies from several inches to greater than 40 inches (USDA Forest Service 2001). The BWCAW and surrounding national forest lands are fire dependent ecosystems relying on periodic fire to “drive nutrient cycling, energy pathways, and help maintain the diversity, productivity, and long-term stability of the ecosystem” (Heinselman 1973). The historical tree species composition on the landscape includes jack pine (*Pinus banksiana*), eastern white pine (*P. strobus*), red pine (*P. resinosa*), black spruce (*Picea mariana*), white spruce (*P. glauca*), balsam fir (*Abies balsamea*), paper birch (*Betula papyrifera*), and trembling aspen (*Populus tremuloides*). The percent composition of these species has changed over the last 100 years due to fire suppression. The jack pine cover type still covers a large proportion of the landscape, but the white pine and red pine cover types have shrunk as the area occupied by the aspen/birch cover type continues to increase (Freidman et al. 2000, USDA Forest Service 2001).

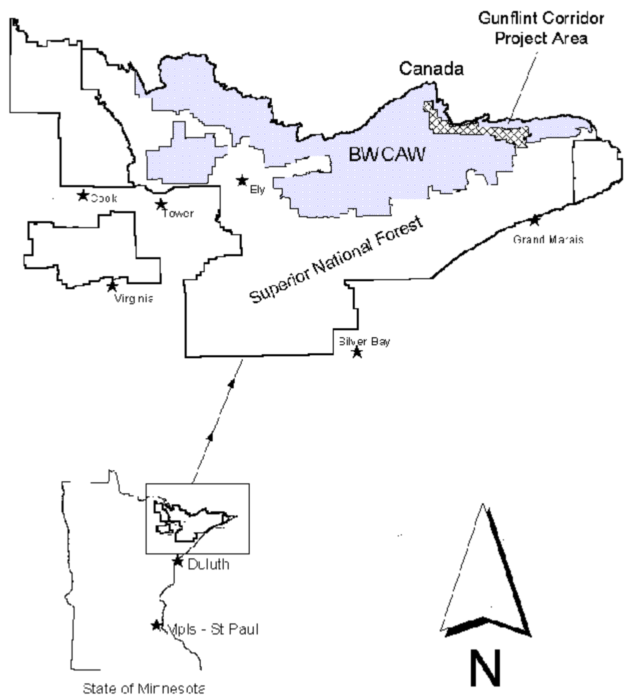


**Figure 1. Location of the study area within the Gunflint Corridor located along the Gunflint Trail northwest of Grand Marais, Minnesota. From USDA Forest Service (2000)**

**Table 1. Ownership distribution of the acreage affected by the July 4, 1999 Independence Day Storm.**

| Ownership | Area affected (acres) |
|---|---|
| • Federal | 473,773 |
|    • Wilderness (BWCAW) | 463,215 |
|    • Gunflint Corridor | 10,558 |
| • State | 1,325 |
| • County | 293 |
| • Private | 1,609 |
| Total | 477,000 |

## Site Selection

A total of 28 sites (Table 2) were selected in consultation with USDA Forest Service forest management personnel based on their likelihood of having a proposed treatment implemented.

## Experimental Design

The umbrella experimental design for the project included 2 factorial levels and was modified as necessary for individual study components (e.g., direct seeding, arthropod sampling). Factorial levels included 2 cover types (aspen/birch or jack pine), and fuel reduction treatments (non-blow down control, blow down control, prescribed burned, salvage harvested, machine piled). Plots were established using a systematic gird pattern that was modified to fit within stand boundaries. Plot size, plot location, and their juxtaposition varied according to the life form (e.g., tree, shrub, herbaceous) or attribute (e.g., fuel loading, disturbance) being measured. Sixteen permanent vegetation and disturbance plots and 48 semi-permanent disturbance plots, for a total of 64 disturbance plots, were established within each sample stand or site. The majority of sites were 5 acres in size or greater. Plots were located in areas where severe wind throw (67 to 100% wind damage) had occurred and have the greatest likelihood of being salvaged within the next two years (USDA Forest Service 2000).

## Data Collection

**Vegetation, Disturbance, and Fuels Data.** Prior to treatments, units selected for sampling were categorized into medium to heavy blow down or undamaged vegetation either by traversing the site or with the aid of aerial photos taken immediately after the July 4, 1999 wind event and subsequent ground truthing.

**Plot establishment.** Plots were established within sites by selecting a random starting point with consideration of fitting all 64 plots within the stand. A location was established outside of the unit as a starting point and a compass bearing was followed for 30 or 40 meters to the first permanent plot. A pin (20 penny nail) with a fiberglass marker was placed at plot center and orange paint was used to mark points that would aid in plot relocation. Rebar was used in place of the pin on prescribed burn plots. Plot center coordinates were recorded with a GPS unit and a photo was taken at plot center. Three temporary disturbance plots were established at 10-meter intervals. Then, at 40 meters, another permanent plot was established. Then, a 90-degree turn was made, 30 or 40 meters measured off and another 90-degree angle turn made to continue with the next portion of the grid. This process was repeated until 16 vegetation plots and 64 disturbance plots (48 temporary and 16 permanent) were completed. Plots sizes were established in metric units and data were collected in metric units.

**Tree data** were collected from circular 0.02 ha (8 m radius, 200 $m^2$) permanently established plots spaced at 40 m intervals using a grid sampling pattern. Species, dbh (measured at 1.37 m above the ground for trees > 2.5 cm dbh), and tree condition (uprooted, snapped off with height to nearest meter, lean (< 45 degrees, > 45 degrees), damaged standing, or no damage were recorded. Total heights were measured for 3 to 4 of the largest trees of the most common species of wind thrown and standing trees per plot. Average depth of wind thrown trees to the nearest 0.5 m was recorded in the 0.02 ha plot.

**Shrub data** were collected from circular 0.001 ha (1.78 m radius, 10 $m^2$) plots spaced at 40 m intervals and nested within the tree plots using a common center. All woody stems were considered shrubs and included tree species if they were less than 2.5 cm dbh. Shrub diameters were measured at 0.15 m above ground line and categorized into 2 mm classes beginning at 3 mm up to 29+ mm.

**Herbaceous data** were collected from 2 circular 1 $m^2$ (0.56 m radius) plots nested within the tree plots and located 4 m from the tree and shrub plot center, perpendicular to the grid azimuth. Presence/absence data was recorded for all species within the tree plot (0.02 ha) area.

**Pre-treatment disturbance data** were collected from circular 0.001 ha (1.78 m radius, 10 $m^2$) plots spaced at 10 m intervals. Every fourth plot was nested within the permanently established tree and shrub plots. Vegetative cover to the nearest 10% was recorded on each disturbance plot. Disturbance data recorded to quantify the seedling germination environment includes percentage of the area in the plot (to the nearest 10%) that was: undisturbed, covered by wind thrown material, uprooted exposed soil, exposed rock, area occupied by stumps, and occupied by standing water.

**Post-treatment disturbance data** were collected from circular 0.001 ha (1.78 m radius, 10 $m^2$) plots spaced at 10 m intervals between and nested within the tree and shrub plots and established in approximately the same location (± 1 m) as the pre-treatment plots. At 40 m intervals, however, the post- and pre-treatment disturbance plots were established in the center of the tree and shrub plots. Additional data were collected to further quantify the impact of fuel reduction activity on the seedling germination environment in post-treatment plots. Percent cover of mosses/lichens, litter, exposed duff, and exposed soil were recorded at the forest floor level. Percent vegetative cover, the amount of large (> 2.5 cm diameter) and small (< 2.5 cm diameter) slash and blow down were recorded at range of heights above the ground (forest floor, 0 to 0.15 m, 0.15 to 1.0 m, 1 to 2 m, 2 to 3 m, > 3m). In the shrub plots, litter and duff depths, and predominant litter species composition were measured and recorded for each of 4 quadrants. Intensity of harvesting disturbance was also recorded in each of the shrub plot quadrants (Table 3).

**Fuel transects.** Sixteen meter fuel sampling transects (Brown 1974) were established across each of the larger 0.02 ha plots. The 16 m transects included 2 smaller nested transects to measure 1 hr, 10 hr, and 100 hr fuels. In the first 2 m of each transect, 1 hr (0 to 0.6 cm diameter) and 10 hr (2.5 to 7.6 cm diameter) fuels and larger were tallied. In the first 4 m of each transect, 100 hr (2.5 to 7.6 cm diameter) fuels and larger were tallied. Fuels greater than 7.6 cm in diameter are 1000 hour fuels and were measured along the entire 16 m transect. Diameter, condition class (sound, rotten), timing of fall (before or after July 4, 1999), and life stage (dead or alive on July 4, 1999) was recorded for 1000 hr fuels only. At 5, 6, 10, and 11 m intervals along each transect duff and litter depths were recorded. Height of the fuel above the ground was measured at the maximum above ground height within each of the following categories: 0 to 30 cm, 30 to 60 cm, or 60 to 90 cm.

**Direct Seeding Experiment.** To further quantify and contribute to an understanding of post-blow down treatments on regeneration ecology, a direct seeding experiment was integrated within the permanent sample plot design. The direct seeding experiment consisted of broadcasting jack pine, red pine, and white pine seeds at 2 densities (10 and 100 seeds $m^2$) with 2 sowing dates (fall 2000 and spring 2001) on 4 $m^2$ plots. Five replicates of 4 $m^2$ plots were installed at salvaged and unsalvaged jack pine and aspen-birch cover types. Plots in the salvaged sites were rectangular and plots in the unsalvaged sites were circular.

**Soil Sampling and Analyses.** Soil pits were excavated in two undisturbed jack pine and two undisturbed aspen-birch stands. Horizon profiles were described and samples collected from each horizon for physical and chemical analyses. Samples to calculate bulk density were collected at 10 cm intervals from the surface of the mineral soil to a depth of 30 cm.

**Table 2. Cover type, treatment, and number of sample site locations.**

| Treatment | Cover Type | Number of sites | |
|---|---|---|---|
| | | Vegetation sampling | Arthropod sampling[a] |
| Wind thrown/prescribed burned | Aspen/Birch/ Conifer | 3 | 4 |
| | Jack pine | 2 | 4 |
| Wind thrown /salvaged | Aspen/Birch/ Conifer | 6 | 4 |
| | Jack pine | 2 | 4 |
| Wind thrown /salvage/prescribed burned | Aspen/Birch/ Conifer | 1 | |
| Wind thrown /machine piled | Aspen/Birch/ Conifer | 3 | |
| Wind thrown /no salvaged | Aspen/Birch/ Conifer | 3 | 4 |
| | Jack pine | 3 | 4 |
| undisturbed control | Aspen/Birch/ Conifer | 2 | 4 |
| | Jack pine | 3 | 4 |

[a]Aspen/birch/conifer sites were sampled for arthropods using unbaited pitfall traps; jack pine sites were sampled for arthropods using unbaited and baited pitfall traps and baited funnel traps.

**Table 3. Harvesting disturbance and severity categories used to quantify the impact of salvage operations on the forest floor.**

| Severity rating | Type of disturbance |
|---|---|
| 5 | Major skid road, trail, or landing |
| 4 | Rutted at a depth > 20 cm<br>Rutted at a depth between 10 & 20 cm<br>Rutted at a depth < 10 cm |
| 3 | Machine track<br>Surface soil moved<br>Duff & soil mixed |
| 2 | Litter removed<br>Near machine track |
| 1 | Slash or log pile > 1 m in depth<br>Litter intact |
| 0 | Undisturbed<br>Non-soil (stump, rock, etc.) |

## Arthropod Sampling

**General.** In all research sites, transects or grids of arthropod sampling plots were co-localized with or adjacent to vegetation sampling plots (Table 2). This coordination of sampling was intended to facilitate later correlation analyses of arthropod and plant responses to the disturbances. In 2000, arthropod traps were operated from late July/early August to late October and were emptied every 20 to 25 days; in 2001, traps were operated from late May until late October and were emptied every 15 days.

**Carabidae (Ground) and Staphylinidae (Rove) Beetle Sampling.** During the summer of 2000, a total of 72 unbaited pitfall traps were installed in the aspen/birch and jack pine forest cover types. These traps were distributed among six sites of each forest type comprising a total of twelve sites. The six sites in each forest type represented the severely wind-disturbed, wind-disturbed-salvaged and undisturbed forest conditions (2 replicates of each condition per cover type). There were six pitfall traps in each site and they were placed on straight-line transects and were separated by >15 m to reduce trap sampling interactions. Pitfall trap design consisted of an outer (1 L) and an inner (500 ml) plastic cup inserted into small excavations in the forest floor (Spence and Niemelä 1994). An elevated 230 cm square wooden roof was placed over the trap to prevent flooding from rain and disturbance by small mammals. During the summer of 2001, the sampling design was expanded to include 192 traps distributed over 32 sites (16 for each forest type). These sites represented four replicates each of the severely wind-disturbed, wind-disturbed-salvaged, wind-disturbed-prescribe-burned and undisturbed forest in both forest types (Table 2). Again, six pitfall traps were installed per site, but in 2001 the traps were assigned to six sample plots randomly drawn from a grid of 28 plots on each site.

**Rhizophagous Scolytidae (Bark Beetle) and Curculionidae (Weevil) Sampling.** During the summer of 2000, a total of 144 baited pitfall traps were installed in the aspen/birch and jack pine forest cover types. These traps were distributed among the forest and disturbance classes and placed within the sites identically with the unbaited pitfall traps except that there were 12 baited pitfall traps per site with three replicates of each bait treatment or control allocated randomly along two transects (6 traps/transect). The construction of the baited traps was also identical. The twelve traps were each baited with one of three semiochemical blends in ethanol [2% (-)-$\alpha$-pinene, 2% (+)-$\alpha$-pinene, 2% (-)-$\beta$-pinene] and a 100% ethanol control (15 ml total volume). Semiochemical blends released from wicks inserted in glass vials, were selected to target various root collar or root-feeding bark beetles and weevils. When traps were emptied, the location of the trap and its semiochemical bait were not re-randomized within the site. During the summer of 2001, the sampling design was altered to include 80 traps distributed over 16 sites, all located in the jack pine cover type. These sites represented four replicates each of the severely wind-disturbed, wind-disturbed-salvaged, wind-disturbed-prescribe-burned and undisturbed forest conditions (Table 2). Baited pitfall trap sampling in the aspen/birch cover type was discontinued. At each site, five pitfall traps baited with the three semiochemical blends in ethanol, ethanol alone, and an unbaited control were assigned to five sample plots randomly drawn from a grid of 28 plots. When traps were emptied, the inner cups and the associated baits were re-randomized on the five outer cup locations (i.e. among the five plots). In 2001, the 15 ml solutions were released from a plastic bottle (Phero Tech. Inc., Delta, B.C.).

**Scolytidae (Bark), Buprestidae (Metallic Wood-boring) and Cerambycidae (Long-horned) Beetle Sampling.** During the summer of 2000, a total of 324 Lindgren funnel traps were installed in the aspen/birch and jack pine forest cover types. These traps were also distributed among six sites of each forest type comprising a total of twelve sites. The six sites in each forest type represented the severely wind-disturbed, wind-disturbed-salvaged and undisturbed forest conditions (2 replicates of each condition per cover type). There were 27 funnel traps hung on 2.2 m tall iron rebar in each site and the traps were placed on a 7 X 4 grid and separated by >15 m to reduce trap sampling interactions. The 27 traps were each baited with one of eight semiochemical blends or left unbaited (three replicates of each semiochemical treatment). Semiochemical blends were selected to target various bark beetle and woodborer species or groups (Table 4). Trap design consisted of sixteen black plastic funnels attached to each other with a collecting jar at the bottom (Lindgren 1983). When traps were emptied, the location of the trap and its semiochemical bait were not re-randomized within the site. During the summer of 2001, the sampling design was altered to include 160 traps distributed over 16 sites, all located in the jack pine cover type. These sites represented four replicates each of the severely wind-disturbed, wind-disturbed-salvaged, wind-disturbed-prescribe-burned and undisturbed forest conditions (Table 2). Funnel trap sampling in the aspen/birch cover type was discontinued. At each site, ten funnel traps baited with nine semiochemicals and an unbaited control were assigned to ten sample plots randomly drawn from a grid of 28 plots. When traps were emptied, the location of the trap and its semiochemical bait were re-randomized among the ten plots.

**Comparison of Temporal and Spatial Colonization Patterns of Bark Beetles within Undisturbed and Wind-disturbed Jack Pine Sites.** Bark and wood-boring beetle populations associated with mortality and decomposition of jack pine are being monitored to determined if these beetles will attack trees that survived the July 9th, 1999 storm event. During the summer of 2001, standing live (20 trees), standing dead (10 trees), leaning live (10 trees), and downed and dead trees (10 trees) within each of 3 paired (undisturbed, wind-disturbed) sites for a total of 50 trees/sites (300 trees total). Trees were classified, mapped, tagged and visually inspected for beetle activity. If beetle activity was present on standing live trees (e.g., presence of boring holes and/or boring dust piles), a 10 X 10 cm bark sample was peeled and removed. On dead trees, a meter long sample on one side of the tree base was removed. Beetle species, number of individuals, and the number and type of galleries in the phloem and/or xylem were recorded. Additional tree measurements included dbh, height, crown class and age.

**Table 4. Target beetle species for attractants[a] used to bait Lindgren funnel traps.**

| Target Beetle Species | Semiochemicals |
|---|---|
| *Ips grandicollis* | (-)-Ipsenol, (-)-α-Pinene |
| *Ips perroti* [b] | (-)-Ipsenol, (-)-Ipsdienol |
| *Ips perroti* | (-)-Ipsenol, (+)-Ipsdienol |
| *Ips perturbatus* | (-)-Ipsenol, (+)-Ipsdienol, (-)-*cis*-Verbenol |
| *Ips pini* | (+/-)-Ipsdienol, Lanierone |
| *Dendroctonus rufipennis* | (+/-)-Frontalin, (-)-α-Pinene, Methylcyclohexanol |
| *Dendroctonus valens* | (+)-α-Pinene, (-)-β-Pinene |
| *Dryocoetes spp.* [c] | (+/-)-*exo*-Brevicomin, (-)-α-Pinene |
| Target Beetle Families | |
| Buprestidae | Ethanol, α-Pinene |
| Cerambycidae | Ethanol, α-Pinene |

[a] All attractants were purchased from Phero Tech., Inc. (Delta, B.C.) or Sigma-Aldrich (Milwaukee, WI).
[b] *Ips perroti* was sampled with (-)-ipsenol, (-)-ipsdienol, and (-)-*cis*-verbenol in 2000.
[c] *Dryocoetes spp.* was sampled with (+/-)-*endo*-brevicomin alone in 2000.

## PRELIMINARY RESULTS

Data collected during the 2001 field season is currently being combined with data collected in 2000 and future data collection is planned for 2002. Therefore, we stress the preliminary nature of these results.

Data collected in the tree level plots have several important applications. First, these data will be used to quantify the pre-blow down stand structure. Subsequent analyses using height diameter ratios, species composition, and other combinations of variables (e.g., stand age, aspect) will then be performed to explore the susceptibility of stands to blow down. Second, tree-level and plot-level data can be used in the local calibration of the Forest Vegetation Simulator (FVS, Dixon 2001). Specifically, equations to quantify height—diameter relationships (Figure 2) by species, cover type, and other stratification variables will be developed. Finally, the condition of downed woody material will be monitored over time to determine how rapidly fuel loadings and fire danger decreases over time.

Tree and shrub level data will be used as an aid in predicting successional trajectories and future stand condition. Specific analyses include the calculation of pre- and post-blow down, and pre- and post-treatment of total tree and shrub biomass (Ohmann and Grigal 1979, Ohmann et al. 1981, Grigal and Ohmann 1984, Perala and Alban 1994).

No differences were detected in percent germination among species, sowing densities, or cover types in the direct seeding experiment. Only a total of 14 jack pine germinants were tallied for the spring sowing date so results are presented for the fall sowing date only (Table 5). Naturally-regenerated germinants of jack and white pine are evident. The true value of this experiment will become evident over time as we monitor survival and future germination through subsequent sowing treatments.

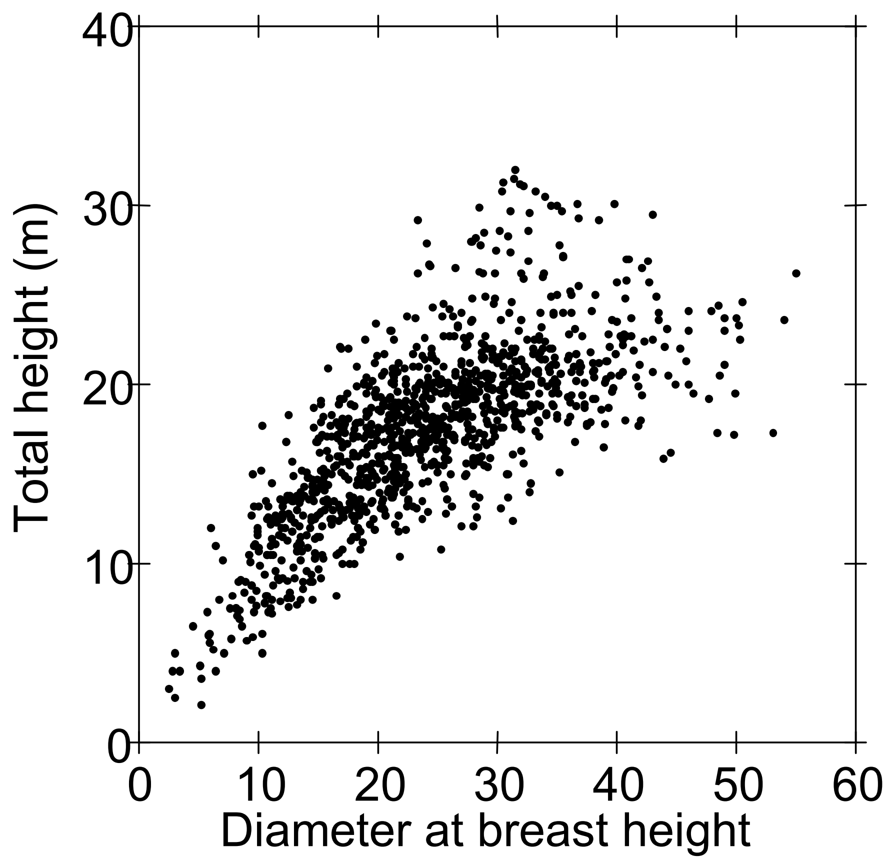


**Figure 2. Graphical depiction of the total height dbh relationship for data collected in 2000 and 2001, all species and all sites combined.**

**Table 5. Percent germination by species and sowing density for seeds sown in the fall of 2000.**

| Species | Treatment (sowing density) | | | |
|---|---|---|---|---|
| | 10 seeds $m^{-2}$ | | 100 seed $m^{-2}$ | |
| | Mean (SE) | Range | Mean (SE) | Range |
| Jack pine | 6.6 (3.2) | 0 to 50% | 7.5 (6.2) | 0 to 130% |
| Red pine | 3.8 (1.7) | 0 to 30% | 2.8 (2.7) | 0 to 52% |
| White pine | 12.5 (8.1) | 0 to 160% | 1.9 (1.4) | 0 to 29% |

Insect samples are being sorted and identified to species-level (Table 6) using available taxonomic keys and expertise from relevant taxonomists. Data will be analyzed according to response over disturbance conditions and according to response to various semiochemicals. Further, we will explore potential correlations between vegetation data on forest structure and composition with arthropod abundance, diversity, and composition. A reference collection of pinned and labeled specimens will be deposited at the University of Minnesota Insect Collection (St. Paul).

**Table 6. Preliminary list of beetle species collected during the summer of 2000.**

| Family | Species |
|---|---|
| Carabidae | *Calathus advena* LeConte |
| | *Pterostichus coracinus* Newman |
| | *Pterostichus melanarius* (Illiger) |
| | *Pterosticus pensylvanicus* LeConte |
| Buprestidae | *Buprestis fasciata* (Fabricius) |
| | *Buprestis maculiventris* (Say) |
| | *Buprestis nutalli* (Kirby) |
| | *Chalcophora virginiensis* (Drury) |
| | *Dicerca callosa callosa* (Casey) |
| | *Dicerca tenebrosa* (Kirby) |
| Cerambycidae | *Acmaeops proteus proteus* (Kirby) |
| | *Monochamus notatus* (Drury) |
| | *Neoclytus* spp. |
| | *Pogonocherus penicillatus* (LeConte) |
| | *Stictoleptura canadensis canadensis* (Olivier) |
| | *Tetropium parvulum* (Casey) |
| Scolytidae | *Ips grandicollis* (Eichhoff) |
| | *Ips perroti* (Swaine) |
| | *Ips perturbatus* (Eichhoff) |
| | *Ips pini* (Say) |
| | *Dendroctonus simplex* (LeConte) |
| | *Dendroctonus valens* (LeConte) |
| | *Polygraphus rufipennis* (Kirby) |
| | *Pityogenes* spp. |

During the 2000 field season, 775 specimens of ground beetles (Carabidae), representing an estimated 33 species, were caught in unbaited pitfall traps. Three species (*Pterostichus caracinus*, n = 176; *P. pensylvanicus*, n = 94; and *Calathus advena*, n = 119) comprised approximately 50% of all specimens trapped in the study. The majority of specimens were trapped in the aspen/birch cover type, and in that cover type the majority were in salvage-harvested stands. Over both cover types, the salvaged sites had higher unique representations of species (aspen-birch, n = 7; jack pine, n = 11). Also among the species trapped in the study was *Pterostichus melanarius*. This species was introduced to both coasts of North American from Europe and has now apparently colonized even the most remote areas of north central North America, including Minnesota (R.A. Haack, personal communication). With baited funnel traps, summer 2000 catches indicated that populations of the pine engraver, *Ips pini,* and the eastern larch beetle, *Dendroctonus simplex* (both Scolytidae), were higher in wind-disturbed stands. Trap catches were higher in the undisturbed and salvage-harvested stands for *I. perturbatus*, and a few cerambycid and buprestid beetle species. Surprisingly, no spruce beetles, *Dendroctonus rufipennis*, were trapped in response to the commercially available bait. Rather, *D. simplex* responded to this bait. We also observed cerambycid beetles attacking live, standing jack pine trees in one wind-disturbed and one undisturbed stand, suggesting that these beetles may cause tree mortality in these sites. Analyses of data from 2001 and all species confirmations by taxonomic experts are pending.

## DISCUSSION

Most stands in the southern boreal forest on Minnesota originated after a high-severity disturbance: either a combination of logging followed by burning of slash, or a crown fire in forests that were not logged (Frelich and Reich 1998). All soils in northeastern Minnesota, however, are not favorable to a species shift from jack pine to aspen following a severe disturbance (Ohmann and Grigal 1975, Frelich and Reich 1998). In New England, salvage operations following the 1938 Hurricane in New England caused greater changes in forest species composition than the hurricane event itself (Foster et al. 1997). In southeastern Alaska, topographic position was reported to influence the likelihood of blow down (Nowacki and Kramer 1998).

Our preliminary findings concur with these results reported in earlier studies. Successional trajectories will be dependant on type of fuel reduction treatment (prescribed burn, harvest) and season of treatment (Anderson et al. 2001). Successful regeneration of pine species will require the exposure of mineral soil. Conifer establishment will also be dependent on site quality (e.g., soil chemical and physical properties, aspect), the influence of competing vegetation, and the proximity of a seed source. The importance of annual re-measurement and monitoring of our permanent plots cannot be understated. For instance, we are detecting and quantifying wind throw and insect mortality that can be attributed to the 1999 storm event. This information is important to forest managers in that it provides insights as to threshold levels of stand density that can be retained following a blow down event or timber harvest in forests of northeastern Minnesota.

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## ABOUT THE AUTHORS

Daniel W. Gilmore, Assistant Professor of Silviculture, Department of Forest Resources, University of Minnesota, North Central Research and Outreach Center, Grand Rapids, MN 55744. dgilmore@umn.edu
Steven J. Seybold, Assistant Professor of Entomology, Departments of Entomology and Forest Resources, University of Minnesota, St Paul, MN 55108. sseybold@umn.edu
John C. Zasada, Project Leader, Silviculture, USDA Forest Service, North Central Research Station, & Adjunct Professor, Department of Forest Resources, University of Minnesota, Grand Rapids, MN 55744. jzasada@fs.fed.us
Paula J. Anderson, Ecologist, USDA Forest Service, Forest Product Laboratory, Grand Rapids, MN 55744. pjanderson@fs.fed.us
Douglas N. Kastendick, Forester, USDA Forest Service, Forest Product Laboratory, Grand Rapids, MN 55744. dkastendick@fs.fed.us
Kamal J.K. Gandhi, Ph.D. student, Departments of Entomology and Forest Resources, University of Minnesota, St Paul, MN 55108. gandh004@tc.umn.edu
Hugh P. Johnson, Masters student, Department of Forest Resources, University of Minnesota, St Paul, MN 55108. john4860@umn.edu

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